MISB MOTION IMAGERY STANDARDS BOARD	MISB ST 1606.1
STANDARD	
MXF Profile for High Performance Motion Imagery Applications	**5 October 2017**

1 Scope

This standard defines a file format for use in high performance and metric imaging applications within the DoD/IC/NSGI. It mandates the Material Exchange Format (MXF), with constraints defined in this document, for capturing, storing, exchange, play out, analysis, and archiving of Motion Imagery. Specifically designed to meet the high precision and accuracy requirements of Major Range and Test Facility Base (MRTFB) applications, this file format supports a wide range of pixel densities, frame rates, bit depths, and color formats, as well as very rich and detailed metadata sets.

This standard supports both uncompressed and compressed imagery consistent with guidance provided by the Motion Imagery Standards Profile (MISP) [1].

This standard directs use of Motion Imagery Sensor Timing Metadata, defined in MISB ST 1507 [2]. This metadata includes a Nano Precision Time Stamp, defined by MISB ST 0603 [3]for timestamps specified to nanosecond resolution. In addition, associated time quality metadata is provided.

This standard supports Audio data, but does not mandate its use.

2 Conformance Language

Normative text describes elements of the standard which are indispensable, or contains the conformance language keywords: "shall", "should", or "may". Informative text is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without material affecting compatibility and interoperability with the standard. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: The Introduction, any section explicitly labeled as "informative", or individual paragraphs beginning with "Note:"

The keyword "shall" indicates requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or, a certain course of action is preferred, but not necessarily required; or, (in the negative form) a certain possibility or course of action is deprecated, but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword “reserved” indicates a provision is not defined at this time, shall not be used, and may be defined in the future. The keyword “forbidden” indicates “reserved”, and in addition, indicates the provision will never be defined in the future.

A conformant implementation in accordance with this document is one which includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may"), and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; tables shall be next; followed by formal languages; then figures; and then any other language forms.

3 References

[1] MISB MISP-2018.1 Motion Imagery Standards Profile, Oct 2017.

[2] MISB ST 1507.2 Motion Imagery Sensor Timing Metadata, Oct 2017.

[3] MISB ST 0603.5 MISP Time System and Timestamps, Oct 2017.

[4] SMPTE ST 377-1:2011 Material Exchange Format (MXF) - File Format Specification.

[5] SMPTE EG 42:2015 Material Exchange Format (MXF) - MXF Descriptive Metadata.

[6] SMPTE ST 379-1:2009 Material Exchange Format (MXF) - MXF Generic Container.

[7] SMPTE ST 380:2004 Television - Material Exchange Format (MXF) - Descriptive Metadata Scheme-1 (Standard, Dynamic).

[8] SMPTE ST 384:2005 Television - Material Exchange Format (MXF) - Mapping of Uncompressed Pictures into the Generic Container.

[9] SMPTE ST 336:2007 Data Encoding Protocol Using Key-Length-Value.

[10] SMPTE ST 378:2004 Television - Material Exchange Format (MXF) - Operational Pattern 1A (Single Item, Single Package).

[11] SMPTE ST 379-2-2010 Material Exchange Format (MXF) - MXF Constrained Generic Container.

[12] MISB ST 0102.12 Security Metadata Universal and Local Sets for Digital Motion Imagery, Jun 2017.

[13] AMWA Application Specification AS-07: MXF Archive and Preservation Format

[14] MISB ST 1603.2 Time Transfer Pack, Oct 2017.

[15] SMPTE ST 394:2006 Television - Material Exchange Format (MXF) - System Scheme 1 for the MXF Generic Container.

[16] SMPTE ST 389:2005 Television - Material Exchange Format (MXF) - MXF Generic Container Reverse Play System Element.

[17] SMPTE RP 224v12:2012 SMPTE Labels Register.

[18] SMPTE ST 422:2014 Material Exchange Format (MXF) - Mapping JPEG 2000 Codestreams into the MXF Generic Container.

[19] SMPTE ST 381-3:2013 Television - Material Exchange Format (MXF) - Mapping AVC Streams into the MXF Generic Container.

[20] ISO/IEC 13818-1:2015 Information technology - Generic coding of moving pictures and associated audio information: Systems.

4 Terms and Definitions

Timestamp	A value of time which represents when an image or event is captured.
DM Segment	An MXF structure used to generically contain Descriptive Metadata on a track. See SMPTE ST 377-1 [4].
Essence	Motion Imagery, metadata, or audio data
KAG	KLV Alignment Grid - A notional byte spacing which may be used to align KLV items within a Partition.
KLV Fill	Refers to the well-defined means of inserting empty, "fill", data in an MXF file. See SMPTE ST 377-1 [4].
DMS Scheme Label	The value stored in an MXF file's Preface::DMSSchemes property. See SMPTE EG 42 [5].

5 Acronyms

AES3	Audio Engineering Society 3 (professional digital audio transport)
DM	Descriptive Metadata
DMS	Descriptive Metadata Scheme
DoD	Department of Defense
IC	Intelligence Community
IRIG	Inter-Range Instrumentation Group
KLV	Key-Length-Value
LS	Local Set
MISP	Motion Imagery Standards Profile
MRTFB	Major Range and Test Facility Base
MXF	Material Exchange Format
NSG	National System for Geospatial Intelligence
RCC	Range Commander's Council
RCC-OSG	Range Commander's Council Optical Systems Group
SMPTE	Society of Motion Picture and Television Engineers
UDS	Universal Documentation System
UL	Universal Label

6 Revision History

Revision	Date	Summary of Changes
ST 1606.1	10/5/2017	• Changed "Enhanced Precision Time Stamp" to "Nano Precision Time Stamp"

		• Changed “Enhanced Precision Time Stamp Pack” to “Nano Precision Time Stamp Pack” • Updated Figure 5 • Updated references

7 Introduction (Informative)

The Major Range and Test Facility Bases (MRTFB) are DoD facilities which support developmental and operational testing of DoD systems. They also support the testing of other government and commercial systems. When testing occurs, Motion Imagery is frequently collected for analysis of test results and system performance. The Range Commander’s Council Optical Systems Group (RCC-OSG) is the coordination body responsible for Motion Imagery activities throughput the MRTFB. This document has been developed in coordination with the RCC-OSG.

Metric Motion Imagery is used heavily in many applications at the DoD test and evaluation ranges. High speed visible and infrared imaging, long range optics, surveillance, laser imaging, astronomy, and radiometry are common examples of high performance Motion Imagery. Because of the nature of the data captured and analysis performed, these use cases dictate formats which vary considerably from those governing commercial broadcast standards.

The MRTFB utilize a large installed base of high-speed, high-resolution, infrared, machine vision, broadcast, and legacy format Motion Imagery equipment producing a myriad of vendor proprietary and range-specific Motion Imagery file formats. Historically, most utilize vendor specific, proprietary and “home grown” file formats. As a result, interoperability across the DoD/IC/NSG suffers greatly across these application areas. Additionally, this lack of standardization significantly hampers the efficiency of many range mission execution activities. This standard should facilitate interoperability throughout the imaging workflow from acquisition to delivery of products and archival. This standard also enables the test ranges to modernize their software and systems, thereby realizing desired efficiencies within existing and future systems.

Leveraging the MXF file format will significantly improve interoperability and operational efficiency. To account for infrastructure or resource-constrained applications where compressed files are needed, this standard at present supports MISP-approved Class 2 Motion Imagery JPEG2000 and H.264/AVC compression technologies. As use cases, requirements and technology advances, this standard is envisioned to evolve as necessary.

8 File Format Description

MISB ST 1606 mandates the use of SMPTE ST 377-1 [4] Material Exchange Format (MXF) and SMPTE 379-2 [6] MXF Constrained Generic Container. Many documents, listed in the References, describe the content and formatting options for Motion Imagery, audio, and mission metadata, which may be contained within a MISB ST 1606 file. Developers and implementers are encouraged to acquire the appropriate documents and other relevant references, as they provide detailed information on options available for file content and configuration. Both

commercial and open-source software libraries and development tools for working with MXF files are readily available.

With the goal of maximizing interoperability within the MRTFB and other DoD/IC/NSG communities who deal in high performance imaging, constraints are placed on the construction of MISB ST 1606 Motion Imagery files. As the use of this format evolves, these constraints will likely evolve based on implementer and end-user needs, with the caveat that interoperability will remain a consistent, high priority requirement.

MXF is a generic container format which supports a wide variety of Motion Imagery, audio, and metadata content. The general MXF file structure, shown in Figure 1, consists of a Header, followed by a Body, and ending with a Footer. The Header portion contains information describing the structure, format and content of the file. It may also contain descriptive metadata pertaining to the image content. For MRTFB applications, this may entail mission descriptions, project details, instrumentation information and settings, etc.

Figure 1: Generic structure of an MXF file.

MXF contains a descriptive metadata plug-in scheme as described in SMPTE EG 42 [5] and SMPTE 380 [7]. The development and documentation of an MRTFB descriptive metadata scheme is outside the scope of this document. Motion Imagery content, mandatory timestamps, optional sampled mission metadata and optional audio content, are stored in the Body portion of the file.

In the Footer portion of the file, an index table and a random index pack improve performance when seeking to frames of interest. Additional metadata may be stored in the Footer when an application dictates the need.

The specific formatting of an index table is tied to the type of Essence stored in the file, and is described in the appropriate content standard of interest. For instance, for uncompressed Motion Imagery, the structure of the index table is defined in Annex A of SMPTE ST 384 [8]. While optional in an MXF file, the random index pack is mandatory for a MISB ST 1606 file. The random index pack is a feature, which allows for quickly finding the location of partitions and major file components within a file. The basic structure of a MISB ST 1606 file is shown in Figure 2. It is important to note this is but one of a multiple number of ways to arrange these elements within a file.

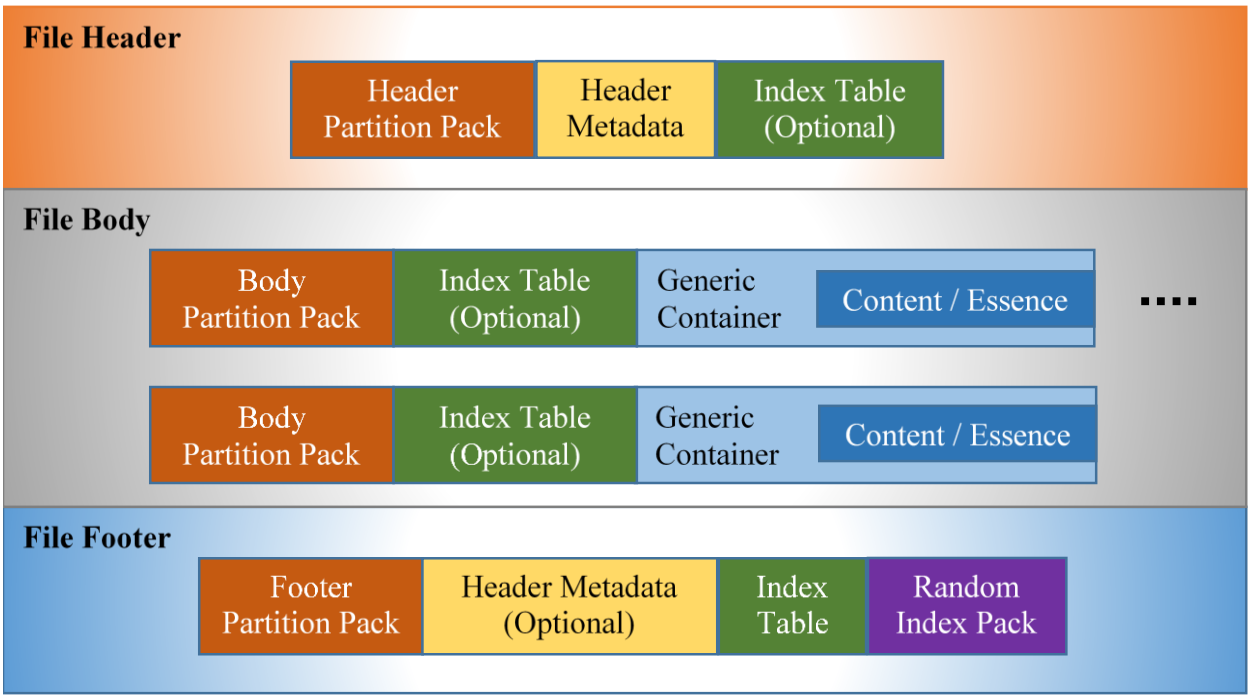

Figure 2: Structure of a MISB ST 1606 file.

8.1 General

Guidelines for the implementation and use of MXF in general DoD/IC/NSG applications are defined in the MISP. Implementers and users of this standard are directed to familiarize themselves with the additional MXF requirements as spelled out in the latest version of the MISP.

8.1.1 Data Encoding

Data within a MXF file is KLV encoded according to the rules in SMPTE ST 336 [9] and SMPTE 377-1 [4]. In applications using rotating disk-based recorders and players, KLV alignment grids (KAG), fill packets, and other appropriate features may be leveraged whenever possible to construct files optimized for reading and writing. By aligning file reads and writes with the sector boundaries of the file system on a disk, performance can be significantly improved compared to the continuous and consistent movement of the disk heads during reading and writing. Use of these features are optional, but highly encouraged, within a file writing device, also referred to as an encoder. File reading devices, referred to as decoders, are required to account for and handle these items when present within a file.

Requirement(s)	
ST 1606-01	Where the KLV alignment grid (KAG) is not defined, the default value shall be 1.
ST 1606-02	Decoders shall process KLV fill items when found within a file.
ST 1606-03	Decoders shall process MXF conformant, encoder-defined KLV alignment grid (KAG) values.

ST 1606-04	Decoders shall ignore unknown KLV items found in a file.

8.2 File Header

The File Header is composed of a Header Partition Pack, Header Metadata, and an optional Index Table.

8.2.1 Header Partition Pack

A MISB ST 1606 file begins with the Header Partition. The Header Partition includes: structural metadata, essence descriptors, and information about descriptive metadata in the file. The Header Partition begins with a 16-byte key, which identifies it as a header partition (KLV) pack. Note that to quickly access if a file is an MXF file, the first 11 bytes of the file can be evaluated and confirmed to be equivalent to the first 11 bytes of the header partition key. The 12th byte is a version number, which may change over time. MXF allows some specialized operational patterns to include a user specified "run-in" sequence of bytes before the 16-byte key of the header partition pack. This special run-in sequence is not allowed in MISB ST 1606 files.

Requirement(s)	
ST 1606-05	A MISB ST 1606 file shall begin with a 16-byte key for the Header Partition Pack.
ST 1606-06	The length of the MXF optional "run-in" sequence shall be zero (0).

8.2.2 Header Metadata

Structural metadata for a MISB ST 1606 file is defined by the Structural Metadata scheme in SMPTE ST 377-1. This scheme is the only one allowed for MXF files, but it is configured to be extensible. As such, MISB ST 1606 specific metadata can be added to this scheme over time. The contents of a specific structural metadata implementation are also further determined by the operational pattern used.

MXF utilizes operational patterns to define the arrangement of information within a file, and therefore, its complexity. Item complexity and package complexity for file content are both defined in SMPTE 377-1, and arranged into a table of operational patterns ranging from low-to-high complexity. To limit the implementation challenges and complexity of MISB ST 1606 files, this document defines those operational patterns which are allowed. As use of this standard evolves, additional operational patterns may be added, depending on the needs of implementers and uses for the standard.

Requirement(s)	
ST 1606-07	MISB ST 1606 files shall use the MXF operational pattern OP1a as defined in SMPTE ST 377-1 [4] and SMPTE ST 378 [10].
ST 1606-08	MISB ST 1606 header metadata shall conform to SMPTE ST 377-1 [4] and SMPTE ST 378 [10] OP1a.

As new header metadata is added over time, it is important for decoder systems to handle unfamiliar metadata. The KLV nature of MXF makes this capability straightforward; a key or tag not understood is skipped over the unknown parameter using the length of the triplet. Dark data is data not understood by a decoder. When encountered, dark data is not required to be interpreted, but should also not affect the ability to continue the reading of other parts of the file. To provide for adding metadata to an existing MISB ST 1606 file, implementations should include a KLV Fill of at least 8 kilobytes in length following the metadata in the header partition.

MISB ST 1606 follows the implementation of the MXF Constrained Generic Container as defined in SMPTE 379-2 [11] As such, the methods for linking header metadata with essence content and other metadata found inside the Generic Container are to be followed.

Requirement(s)	
ST 1606-09	A ContainerConstraintSubDescriptor shall be added to the GenericDescriptor::SubDescriptors property of the top-most File Descriptor describing the essence container in accordance with SMPTE ST 379-2 [11]
ST 1606-10	The method for linking a Header Metadata Track and an Essence Element shall follow the method as defined in SMPTE ST 379-2 [11]
ST 1606-11	The method for linking a Header Metadata Track and a System Element shall follow the method defined in SMPTE ST 379-2 [11].

8.2.3 Descriptive Metadata

MISB ST 1606 files may implement a Descriptive Metadata Scheme, which encodes metadata in a Descriptive Metadata track. The definition of specific descriptive metadata for use with MISB ST 1606 is considered outside the scope of this document. Examples of descriptive metadata which may be appropriate for MISB ST 1606 include classification information (as per MISB ST 0102 [12]), RCC Universal Documentation System (UDS) mission parameters, etc. Readers are encouraged to check with the MISB for availability of applicable MRTFB Descriptive Metadata Schemes. Descriptive metadata schemes which are utilized in MISB ST 1606 files are to be added to the Material Package as per SMPTE ST 377-1 and SMPTE EG 42. To provide for the future addition of metadata to existing MISB ST 1606 files, implementations should consider including a KLV Fill of at least 8 kilobytes in length following the metadata in the header partition. This follows guidance from AMWA AS-07 [13].

Requirement(s)	
ST 1606-12	Descriptive metadata schemes used in a MISB ST 1606 file shall be identified by the use of a DM Scheme label contained in the MXF Preface::DMSchemes property.
ST 1606-13	Each metadata scheme with an associated specialized DM Framework shall be contained within a dedicated Descriptive Metadata Track.
ST 1606-14	MISB ST 1606 metadata scheme definitions shall fully specify a DM Scheme Label which identifies the scheme, the scheme's specialized DM Framework, and the individual metadata items which are contained by the scheme's specialized DM Framework.

8.3 The File Body

The primary function of the MXF file body is to encapsulate the media essence. The media essence includes Motion Imagery, metadata and optionally audio. To help facilitate efficient and ready access to the media, as well as file recovery in the case of errors, a MISB ST 1606 file utilizes the body partitioning mechanism provided by MXF. To facilitate consistent organization of the content, a MISB ST 1606 file utilizes the Generic Container (as defined in SMPTE ST 379-1 and SMPTE ST 379-2).

8.3.1 Body Partition(s)

The use of body partitions in an MXF file helps to facilitate segmentation of Index Tables, to assist in full or partial file recovery when part of the file gets corrupted, and to facilitate mechanisms for efficient file access for large files. The use of Body Partitions within a MISB ST 1606 file is required.

Requirement(s)	
ST 1606-15	A MISB ST 1606 Motion Imagery file shall utilize body partitions.
ST 1606-16	A minimum of one (1) body partition shall be present.

The frequency of body partition insertion is application dependent and implementers are encouraged to consider the trade-space associated with their use and frequency of implementation. Many industry-derived MXF implementations are based on broadcast use cases where frame rates are typically 30 or 60 Hz. MRTFB applications are unrestricted with respect to frame rate, so body partitions based on traditional broadcast time increments may not be appropriate for test range applications. In general, for MRTFB implementations, consideration should be given to the number of Motion Imagery frames, rather than a quantity of time when determining an appropriate frequency of body partition usage.

8.3.2 Generic Container

To support the goals of interoperability and consistency in the implementation of conformant MRTFB Motion Imagery files, the use of the generic container for all MISB ST 1606 Motion Imagery files is mandatory.

Requirement	
ST 1606-17	A MISB ST 1606 Motion Imagery file shall utilize the MXF Generic Container, as per SMPTE ST 379-2 [11], to wrap essence content within the body of the file.

The generic container provides a standardized and consistent mechanism for wrapping Motion Imagery, metadata, and audio. To accomplish this, MXF defines five types of items which can be placed within the generic container: The System Item, the Picture Item, the Sound Item, the Data Item, and the Compound Item.

The first item within the Generic Container of a MISB ST 1606 file is the System Item. This is then followed by one or more of the other item types. The basic functionality of each item type is as follows:

1. System Item: The System Item provides a mechanism for linking and tracking data and metadata items within a file. Essence timestamps for individual image frames are also found within the System Item. These timestamps conform to MISB defined timestamps.
2. Picture Item: The Picture Item contains one frame of imagery for frame-wrapped essence, and one or more frames of imagery for clip-wrapped essence.
3. Sound Item: The Sound Item contains samples of sound or audio essence.
4. Data Item: The Data Item contains KLV-encoded metadata. The encoding of this metadata is defined in relevant MISB KLV metadata set documents.
5. Compound Item: The Compound Item contains items which cannot be easily separated, such as an interleaved MPEG-2 transport stream containing video, audio, and metadata.

The Compound Item includes a mixture of different indivisible essence types. An example might be content from an interleaved MPEG-2 transport stream. Compound Items are not considered to be a defined component of a MISB ST 1606 file. Thus, a MISB ST 1606 conformant decoder is required to decipher and handle the System, Picture, Sound and Data Items within the generic container, but not compound items.

Requirement(s)	
ST 1606-18	MISB ST 1606 implementations of the generic container shall contain a System Item and a Picture Item, and may contain Sound and Data items.
ST 1606-19	A MISB ST 1606 decoder shall decode the System Item, the Picture Item, the Sound Item, and the Data Item within the generic container.

8.3.2.1 Content Wrapping

SMPTE ST 379-2 defines content wrapping methods via clip wrapping and frame wrapping. Files conforming to MISB ST 1606 may only use frame wrapping. Clip wrapping and line wrapping, as defined in SMPTE ST 384 for uncompressed imagery, are not allowed. The reason for this restriction is driven by current trends with MXF implementation as well as a desire for improved interoperability, which is facilitated by a constrained set of implementation requirements.

Requirement	
ST 1606-20	MISB ST 1606 files shall utilize frame wrapping only.

The figures below provide a view of how content can be arranged within a file in frame wrapping mode. Figure 3 shows the arrangement of image frames in a frame wrapped configuration with no other essence elements.

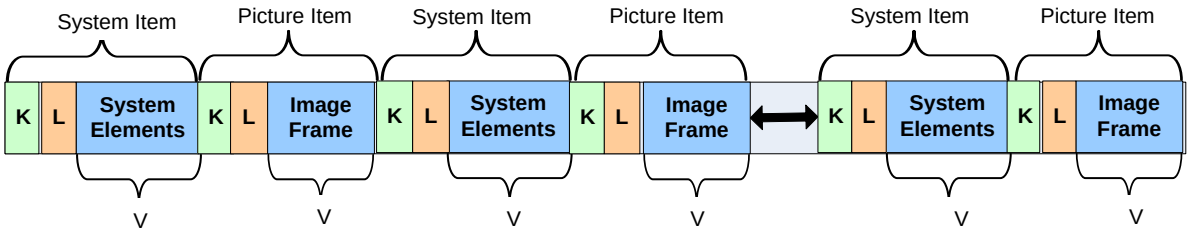

Figure 3: Frame wrapping of only Picture Items.

Figure 4 shows the arrangement of image frames in a frame wrapped configuration with two channels of audio and a data channel element also present.

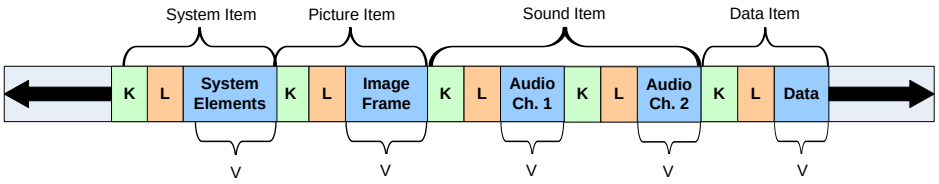

Figure 4: Frame wrapping of Picture, Sound and Data Items.

8.3.2.2 System Item

The System Item is not intended to carry metadata which would normally be carried within the MXF Header Metadata, or within a data partition in the generic container. It is intended to carry metadata as it relates to – or describes – a feature of a specific frame or frames of essence data carried within the same content package. Guidance and rules for placing metadata in a MISB ST 1606 System Item are defined by SMPTE ST 379-2 and SMPTE ST 394. Specific care needs to be taken in following the approach for linking header metadata with system elements, and with essence content within the Generic Container.

For MISB ST 1606 files, the primary metadata required to be carried within the System Item is the Motion Imagery Sensor Timing Metadata, as defined in MISB ST 1507, which includes a Time Transfer Pack. The Nano Time Transfer Pack (specified by MISB ST 1603 [14]) provides a KLV pack constructs comprised of a Nano Precision Time Stamp, and the Time Transfer Local Set, which adds information regarding the quality of the timestamp. In this document, the Nano Precision Time Stamp is required to be present with each frame of imagery. Additional use-case-specific metadata may be placed within the System Item, but is not required.

Requirement(s)	
ST 1606-21	The System Item within MISB ST 1606 files shall be formatted in accordance with SMPTE ST 379-2 [11] and SMPTE ST 394 [15].
ST 1606-22	The System Item shall be present in all Content Packages.
ST 1606-23	MISB ST 1606 files shall use the GC-Compatible System Item with the coding value of 0x14 in Byte 13 of the System Item Metadata Element.

As per SMPTE ST 394, the first item to appear in a Content Package of a Generic Container is the first System Element of the System Item, which carries the Element Identifier of 0x01. Metadata included within this System Element applies to the current Content Package. The UL (key) for this first element is defined in SMPTE ST 394, and is shown in Table 1 below with MISB ST 1606 constraints applied:

Table 1: The UL (key) for the First System Element of the System Item in a MISB ST 1606 File.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x02	Sets and Packs
6	Registry Designator	0xXX (see SMPTE ST 336)	Fixed-length Pack, Variable-length Pack or Local Set as required
7	Structure Designator	0x01	Sets and Packs Registry
8	Version Number	0xVV	Registry Version at the point of registration of this Key
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association
11	Application	0x03	MXF Generic Container Keys
12	Structure Version	0x01	MXF-GC Version 1
13	Item Type Identifier	0x14	GC-Compatible System Item
14	System Scheme Identifier	0x02	GC System Scheme 1
15	Metadata or Control Element Identifier	0x01	First Element
16	Element Number	0xXX	Unique Element Instance Number (Always 0x00 for the First Content Package)

If no metadata is required to be carried within the value portion of the first System Element, a value of "0" may be applied to the length value. Since it is always first and always present, this key can be used by decoders to identify an unambiguous starting point of a Content Package.

8.3.2.2.1 MISB Motion Imagery Sensor Timing Metadata

Each Motion Imagery frame within a MISB ST 1606 file requires a timestamp. The Nano Precision Time Stamp defined in MISB ST 0603, encoded into the Nano Time Transfer Pack defined in MISB ST 1603, and carried within a MISB ST 1507 Local Set (LS), provides 64-bit nanosecond resolution, with an Epoch as defined in MISB ST 0603. MISB ST 1603 defines the elements of the Time Transfer Local Set, which is metadata describing the source, quality, and status of the timing source. The use cases for MISB ST 1606 require sufficient time resolution for applications with frame rates into the millions of frames per second. The Nano Time Transfer Pack is embedded in a MISB ST 1507 LS, as shown in Figure 5.

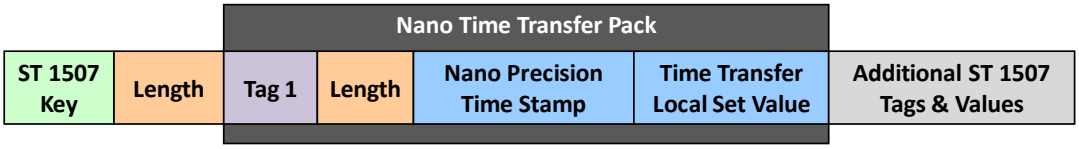

Figure 5: The Nano Precision Time Stamp encapsulated within a Nano Time Transfer Pack as an element of MISB ST 1507 LS.

To implement the Nano Precision Time Stamp within a MISB ST 1606 file, the Nano Time Transfer Pack, as an element of the MISB ST 1507 LS, is placed inside the System Element. SMPTE ST 394 identifies a System Element which is by definition, bound to the Picture Item within the Generic Container. This System Element has an Element Identifier of 0x03 (Byte 15 of the System Element Key (see Table 2). This association binds the Motion Imagery Sensor Timing Metadata, which includes the Nano Precision Time Stamp, to the individual frame of Motion Imagery contained within the frame-wrapped Content Package.

Requirement(s)	
ST 1606-24	Every image frame of a MISB ST 1606 file shall have an associated MISB ST 1507 Motion Imagery Sensor Timing Metadata Local Set included in each System Element.
ST 1606-25	A MISB ST 1507 Motion Imagery Sensor Timing Metadata Local Set shall include a Nano Time Transfer Pack (Tag 1).
ST 1606-26	The Element Identifier in the System Element shall be set to '0x03' to bind the Nano Precision Time Stamp and associated metadata to an image frame.
ST 1606-27	Picture items (Motion Imagery) within a content package in the generic container shall act as the primary time base for the content package.

The UL (key) for the System Element which conveys the MISB timestamp information is shown in Table 2.

Table 2: The System Element UL which conveys MISB timestamp information.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x02	Sets and Packs
6	Registry Designator	0xXX (see SMPTE ST 336)	Fixed-length Pack, Variable-length Pack or Local Set as required
7	Structure Designator	0x01	Sets and Packs Registry
8	Version Number	0xVV	Registry Version at the point of registration of this Key
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association

11	Application	0x03	MXF Generic Container Keys
12	Structure Version	0x01	MXF-GC Version 1
13	Item Type Identifier	0x14	GC-Compatible System Item
14	System Scheme Identifier	0x02	GC System Scheme 1
15	Metadata or Control Element Identifier	0x03	System Element #3
16	Element Number	0xXX	Unique Element Instance Number (Always 0x00 for the First Content Package)

Figure 6 shows the generalized configuration for the Content Package of a MISB ST 1606 file.

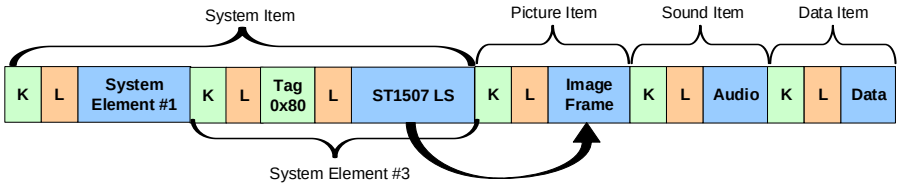

Figure 6: The general configuration of a Content Package in a MISB ST 1606 file.

To support a generalized and extensible metadata capability within System Element #3, a Local Set is defined. This Local Set contains a tag for the Motion Imagery Sensor Timing Metadata Local Set, as shown in Table 3 and is extensible via the addition of new tags. Currently, no additional tags are defined.

Table 3: System Element Picture Item Local Set.

Tag	Element Name	Key Value (hex)	Usage	Reference
80.00h	Motion Imagery Sensor Timing Metadata Local Set	06.0E.2B.34.02.0B.01.01 0E.01.03.02.01.00.00.00 (CRC 13079)	Every Frame	MISB ST 1507 [2]
80.01h	TBD (Future Extensions)			

8.3.2.2.2 Reverse Play Element

MXF has an option for a reverse play element, which allows for efficient access to frames when operating in a reverse direction, VCR playout mode. All MISB ST 1606 encoders and decoders should implement the reverse play element as defined in SMPTE ST 389 [16].

8.3.2.3 Motion Imagery Essence

This standard is intended to support a wide variety of MRTFB Motion Imagery applications. Content types include both broadcast and non-broadcast Motion Imagery formats. Scientific and machine vision cameras will find application with the MISB ST 1606 format. Image content may be sourced from image sensors with the following characteristics and capabilities:

- High speed
- High bit depth
- Standard and non-standard color formats, including monochrome
- Bayer encoded color
- Radiometers
- Infrared in all bands
- Ultraviolet
- High resolution and low resolution
- Low frame rate and high frame rate (into the billions of frames/second for specialized applications)
- Etc.

Requirement(s)	
ST 1606-28	Motion Imagery content shall be sourced and stored as full frame, progressive (non-interlaced) Motion Imagery.
ST 1606-29	Motion Imagery content shall follow the rules of the appropriate content standard.

Allowed Motion Imagery essence types for MISB ST 1606 files include both uncompressed and compressed formats using JPEG2000, and H.264/AVC. Details of the rules for content wrapping for each individual format are found in their respective standards. Label and key information with associated MISB ST 1606 constraints applied are shown in the sections following.

8.3.2.3.1 Uncompressed Motion Imagery Essence

For uncompressed content, the UL (key) value for the uncompressed picture element and its allowed options for this standard are defined in Table 4 (see SMPTE ST 384).

Table 4: Key value for the uncompressed picture element.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label Size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x04	Labels
6	Registry Designator	0x01	Labels Registry
7	Structure Designator	0x01	Labels Structure
8	Version Number	0xvv	Version of the Registry
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association
11	Application	0x03	Essence containers
12	Structure Version	0x01	Version 1

13	Item Type Identifier	0x15	GC Picture Item (as defined in SMPTE ST 379-1 [6] and SMPTE ST 379-2 [11])
14	Essence Element Count	0x01	Count of Picture Elements in the Picture item
15	Essence Element Type	0x02	Frame Wrapped Uncompressed Picture Element
16	Essence Element Number	0x01	The Number (used as an Index) of this Picture Element in the Picture Item

For uncompressed content, the generic container UL (key) is defined as follows in Table 5.

Table 5: Specification of the uncompressed picture essence container label.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label Size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x04	Labels
6	Registry Designator	0x01	Labels Registry
7	Structure Designator	0x01	Labels Structure
8	Version Number	0xvv	Version of the Registry
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association
11	Application	0x03	Essence containers
12	Structure Version	0x01	Version 1
13	Essence Container Kind	0x02	MXF Generic Container
14	Mapping Kind	0x05	Uncompressed Pictures as listed in SMPTE RP 224 [17]
15	Number of lines / field rate combination	0x00	Not used
		0xXX	See SMPTE RP 224 [17]
		0x7F	Number of Lines and Frame rate must be determined from the Essence Descriptor
16	Wrapping Type	0x01	Byte 15 = 0x7F Frame Wrapping
		0xYY	Byte 15 = 0xXX Frame Wrapping

8.3.2.3.2 JPEG2000 Compressed Motion Imagery Essence

For JPEG2000 compressed content, the UL (key) value for the compressed picture element and its allowed options for this standard are defined in Table 6 (SMPTE ST 422 [18]).

Table 6: Key value for the JPEG 2000 picture element.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label Size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x04	Labels
6	Registry Designator	0x01	Labels Registry
7	Structure Designator	0x01	Labels Structure
8	Version Number	0xvv	Version of the Registry
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association
11	Application	0x03	Essence containers
12	Structure Version	0x01	Version 1
13	Item Type Identifier	0x15	GC Picture Item (as defined in SMPTE ST 379-1 [6] and SMPTE ST 379-2 [11])
14	Essence Element Count	0x01	Count of Picture Elements in the Picture item
15	Essence Element Type	0x08	Not Clip-wrapped JPEG 2000 Picture Element
16	Essence Element Number	0x01	The Number (used as an Index) of this Picture Element in the Picture Item

For JPEG2000 compressed content, the generic container UL (key) is defined in Table 7.

Table 7: Specification of the JPEG2000 compressed picture essence container label.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label Size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x04	Labels
6	Registry Designator	0x01	Labels Registry
7	Structure Designator	0x01	Labels Structure
8	Version Number	0xvv	Version of the Registry
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association

11	Application	0x03	Essence containers
12	Structure Version	0x01	Version 1
13	Essence Container Kind	0x02	MXF Generic Container (as defined in SMPTE ST 379-1 [6] and SMPTE ST 379-2 [11])
14	Mapping Kind	0x0C	JPEG 2000 Picture Element (as listed in SMPTE RP 224 [17])
15	Content Kind	0x01	"P1" Frame-wrapped Picture Element
16	Reserved	0x00	

8.3.2.3.3 H.264 Compressed Motion Imagery Essence

For H.264/AVC compressed content, the UL (key) value for the compressed picture element and its allowed options for this standard are defined in Table 8 (see SMPTE ST 381-3 [19]).

Table 8: Key value for the H.264/AVC picture element.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label Size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x04	Labels
6	Registry Designator	0x01	Labels Registry
7	Structure Designator	0x01	Labels Structure
8	Version Number	0xvv	Version of the Registry
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association
11	Application	0x03	Essence containers
12	Structure Version	0x01	Version 1
13	Item Type Identifier	0x15	GC Picture Item (as defined in SMPTE ST 379-1 [6] and SMPTE ST 379-2 [11])
14	Essence Element Count	0x01	Count of Picture Elements in the Picture item
15	Essence Element Type	0x05	Frame Wrapped Picture Element
16	Essence Element Number	0x01	The Number (used as an Index) of this Picture Element in the Picture Item

For H.264/AVC compressed content the generic container UL (key) is defined in Table 9.

Table 9: Specification of the H.264/AVC essence container label.

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	0x06	
2	Label Size	0x0E	
3	Designator	0x2B	ISO, ORG
4	Designator	0x34	SMPTE
5	Registry Category Designator	0x04	Labels
6	Registry Designator	0x01	Labels Registry
7	Structure Designator	0x01	Labels Structure
8	Version Number	0xvv	Version of the Registry
9	Item Designator	0x0D	Organizationally Registered
10	Organization	0x01	AAF Association
11	Application	0x03	Essence containers
12	Structure Version	0x01	Version 1
13	Essence Container Kind	0x02	MXF Generic Container (as defined in SMPTE ST 379-1 [6] and SMPTE ST 379-2 [11])
14	Mapping Kind	0x0F 0x10	AVC NAL unit stream AVC byte stream
15	Locally Defined	0xXX	ISO/IEC 13818-1 [20] stream_id bits 6…0 The default value is 60h.
16	Locally Defined	0x01	01h: Frame Wrapping

8.3.2.3.4 Essence Content Endian Format

High dynamic range imagery is common within the MRTFB. For performance reasons, it is desirable to allow an encoder/recorder to save image frames in the native endian format of the source machine. Thus, this standard allows for the support of both endian formats given those options are made available by the relevant essence content standard, which is where endian formats are defined. As such, encoders may encode multi-byte essence as big or little-endian format when allowed by the essence wrapping standard in use.

Requirement(s)	
ST 1606-30	A MISB ST 1606 Motion Imagery file shall include metadata which indicates the endian format of multi-byte essence contained within the file.
ST 1606-31	Where equipped, file readers shall decode essence stored in big and little-endian format.

8.3.2.4 Data Stream: KLV metadata as per MISP

Data and metadata support within the MXF file format provides a key advantage over other formats when used in the MRTFB Motion Imagery application. The KLV nature of MXF allows for the direct support of existing and future MISB metadata sets, including MISB ST 0601, MISB ST 1107, etc. Applications requiring precise timestamp support, location information, gimbal angles, inclusion of lens and camera settings, non-uniformity corrections, bad pixel maps, Bayer coefficients, etc. are now provided with a consistent and standards-based mechanism for metadata inclusion within Motion Imagery files. This provides a rich set of information, greatly benefiting downstream processing, analysis, archival, retrieval, and other functions. As a result, implementers are highly encouraged to fully leverage the metadata capabilities of the MISB ST 1606 file format. Specific information on the implementation of these metadata sets are included in their respective standards and recommended practices. Implementers are encouraged to monitor and participate in the coordination of various metadata Local Sets appropriate for use in MRTFB applications.

Inclusion of metadata within a file can be configured as per SMPTE ST 377-1, SMPTE ST 379-2, and SMPTE ST 384 rules. Linkage to metadata information within an external file separate to the Motion Imagery file is permissible. This option will generally find use in recording applications, where the metadata and Motion Imagery are recorded on separate systems. It is recommended, when possible, the metadata and Motion Imagery be harmonized inside one merged file in the event the Motion Imagery and metadata become separated. This is especially true for files placed into an archive. To correlate sensor metadata with Motion Imagery frame metadata, the timestamps in the imagery are to be included with the metadata as well.

Requirement	
ST 1606-32	To allow for correlation with image frames, secondary sensor metadata shall include timestamps.

8.3.2.5 Audio

Applications may require (or desire) the inclusion of audio content. This standard allows for the encoding and wrapping of audio content within the generic container in MISB ST 1606 Motion Imagery MXF file.

Requirement	
ST 1606-33	Audio included in a MISB ST 1606 file shall follow the guidelines and requirements for audio content per AMWA AS-07: MXF Archive and Preservation Format [13].

8.4 The File Footer

The File Footer is placed at the end of the file. It may include the following items:

1. Footer Partition
    a. Footer Partition Pack
    b. Header Metadata (optional)
    c. Index Table
2. Random Index Pack

The Footer Partition Pack, the Header Metadata (if present), and the Index Table are part of the Footer Partition. The Random Index Pack is not part of the footer partition, but is always to be present as the last item of a MISB ST 1606 file.

8.4.1 Footer Partition Pack

The first item within the file footer is the footer partition pack.

Requirement(s)	
ST 1606-34	The Footer Partition Pack in a MISB ST 1606 file shall always be present.
ST 1606-35	The Footer Partition Pack shall be the first item in the file footer of a MISB ST 1606 file.

8.4.2 Header Metadata

In certain cases, metadata may not be available when a file is first created, or before image frames have been captured. In these cases, it may be appropriate to place additional header metadata within the footer portion of the file. An example might include calibration data collected after a test. Inclusion of header metadata within the footer partition is allowed, but optional. In addition, header metadata may be carried external to the file. Standard MXF mechanisms for linking to external metadata content are allowed.

8.4.3 Index Table

There are many features within MXF which allow for performance improvement. The MXF format provides for optional index tables to provide a mechanism for quick frame lookup and access. The implementation of an index file is mandatory for MRTFB files. While the index table is mandatory in the footer partition, the inclusion of index table segments in other parts of the file is allowed.

Requirement	
ST 1606-36	MISB ST 1606 Motion Imagery files shall include a full index table in the footer which is conformant with the rules outlined in the generic container standard of applicability.

8.4.4 Random Index Pack

The final item in a MISB ST 1606 file is the random index pack. The random index pack provides a mechanism for quickly identifying the location of primary components of an MXF file.

Requirement	
ST 1606-37	A Random Index Pack as defined in SMPTE ST 377-1 [4] shall be the last item in a MISB ST 1606 Motion Imagery.